Adaptation and Technological Change

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Purpose of the talk

Charge: To provide a summary of the state of the science on the influences of adaptation on the social cost of climate change; specifically, discuss

(1) *relevant studies on the observed or potential effectiveness of adaptive measures, and on private behaviors and public projects regarding adaptation;*

(2) *relevant studies on how to forecast adaptive capacity;*

(3) *how adaptation and technical change could be represented in an IAM (for at least one illustrative sector);*

(4) *whether the information required to calibrate such a model is currently available, and, if not, what new research is needed; and*

(5) *how well or poorly existing IAMs incorporate the existing body of evidence on adaptation*

General conclusions

- Modeling adaptation is inherently difficult. Requires advancements in modeling techniques
- Coverage of empirical work on adaptation limited. Requires heroic efforts to bring into IAMs. Need to bridge gap between models and empirical studies.
- Adaptation-related technological change is lacking in current IAMs. More empirical work is needed in this area to inform existing models.

What is unique about the adaptation process?

1. Adaptation is in response to current or anticipated impacts. Comes in two forms:

   - Reactive—e.g., changes in heating/cooling expenditures; treatment of disease; shifts in production
   - Proactive—e.g., infrastructure construction (seawalls); early warning systems; water supply protection investments

Need explicit representation of climate damages to induce reactive expenditures and proactive investment.

What is unique about the adaptation process?

2. Proactive adaptation investment decisions made today to provide possible future protection; decisions are therefore

   - Inherently intertemporal
   - Made under uncertainty

Need model that can allows for intertemporal decision-making under uncertainty.

What is unique about the adaptation process?

3. Is adaptation-related technological change markedly different from mitigation-related technological change?

   - Public R&D versus private R&D?
   - Inducements different?

Need model capable of distinguishing between these two types of technological change.

What is unique about the adaptation process?

4. Impacts and adaptation responses are locally- or regionally-based. Adaptation expenditures are sector-specific.

   Therefore, need model that includes
   - regional detail
   - sectoral detail
   - method to aggregate to more coarse representation

Important model features for adaptation

- Explicit modeling of climate damages/impacts
- Intertemporal decision making under uncertainty
- Endogenous adaptation-related technological change
- Regional and sectoral detail
- Connection with empirical work on impacts and adaptation

Model	Impacts	Regional detail	Sectoral detail	Link to empirical work on adaptation	Intertemporal?	Uncertainty	Adaptation
AD-WITCH	Region-specific climate damage functions	12 regions	Bottom-up energy sector (7)	To separate adaptation costs and residual damages	Optimal growth-Perfect foresight	Application where uncertain R&D modeled implicitly	Investment in proactive, reactive, and knowledge adaptation
AD-DICE/AD-RICE	Region-specific climate damage functions (AD-RICE)	13 regions (AD-RICE)	One aggregate economy for each region	Similar to AD-WITCH	Optimal growth-Perfect foresight		Adaptation investment included as decision variable
PAGE	Region-specific damage functions for two sectors (economic and noneconomic)	8 regions	One economic sector for each region	IPCC TAR?	Simulation model	Stochastically models catastrophic events	Simple adaptation included which increases tolerable level
FUND	Damage function for each of 8 sectors	9 regions	8 market and non-market sectors	Limited	Simulation model	Application with monte carlo simulation	Explicit in ag and coastal sectors; implicit in energy and human health
GTAP-E/GTAP-EF	Used for separate impact studies	8 regions	CGE-8 or 17 sectors	Limited	Static		
ICES	Models 5 impacts simultaneously	8 regions	CGE-17 sectors		Dynamic recursive		
FARM	Sea level rise and impacts on agric	12 regions—detailed	CGE-13 sectors	Limited	Static		Coastal protection

Empirical studies on adaptation

- Agrawala and Fankhauser (2008)—OECD publication which summarizes empirical work on adaptations costs.
  - Sectors include: coastal zones; agriculture; water resources; energy demand; infrastructure; tourism; and public health.
- World Bank (2010)—report from the Economics of Adaptation to Climate Change (EACC) research program at WB
  - Seven sector-specific studies on adaptation costs: infrastructure; coastal zones; water supply and flood protection; agriculture; fisheries; human health; extreme weather events
- UNFCCC (2007)—Four regional (Africa, Asia, Latin America, and small island developing States) studies on vulnerability, and current and future adaptation plans/strategies.
  - Information from UNFCCC National Communications, regional workshops, and expert meetings.

Recommended future research areas—Decision making under uncertainty

- Past approaches involve:
  1. Create multiple States of the World (SOWs)
  2. Index all variables and equations in model by SOW.
  3. Solve by constraining decision variable to have single value across SOWs in all time periods before information is known.

- Problem with this approach: Rapidly becomes intractable for more than a few SOWs.

- New research by Mort Webster (MIT) applying Approximate Dynamic Programming introduced by Powell (2007):
  1. Sample state space using Monte Carlo techniques
  2. Approximate value function from these samples
  3. Solve for approximate optimal policy using these approximate value functions

Recommended future research areas—Adaptation-related technological change

- Adaptation-related technological change largely absent in current models
- Most models calibrated based on current adaptation cost estimates. No allowance for technological improvements.
  - Exception: AD-WITCH includes investment in adaptation knowledge which lowers future cost of adaptation. Only applied to health care sector.
- Lack of empirical studies limits modeler's ability to represent adaptation-related technological change in current models
- More empirical work in this area is desperately needed

Recommended future research areas—Empirical work on adaptive capacity

- Regional differences in adaptive capacity important to capture in models. Will affect distributional effects of climate impacts
- Largely absent in existing models
  - Exceptions:
    - FUND model assumes wealthier nations less vulnerable to climate impacts in the energy and health sectors.
    - AD-WITCH's investment in adaptation knowledge also captures expenditures to improve region's ability to adapt
- Although in both cases, modelers were limited by lack of empirical data. UNFCCC (2007) provides adaptive capacity measure but only for four aggregate regions.
- Heroic efforts required to translate this little empirical information to model parameters

Recommended future research areas—Dynamics of recovery

- Lack of empirical evidence on the dynamics of recovery from climate change impacts.
  - E.g., time to recovery, thresholds and factors affecting these variables
- Important for model calibration
- In general, need techniques to better translate results from empirical studies to models; e.g.,
  - Regional and sectoral detail do not typically align

*** Going forward, we need to devise better ways to facilitate communication between empirical researchers and modelers.

Questions?/Discussion?